The Army's Flexible Display Center (FDC) at Arizona State University (ASU)

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The first commercial flat panel displays appeared less than 20 years ago with the advent of the now ubiquitous laptop computer. Since then, these important electronic devices have become an indispensable component of the infrastructure of our increasingly networked world. Consumer electronics such as laptop computers, personal digital assistants (PDAs), cellular telephones and an increasing variety of portable information and entertainment devices all depend on flat panel displays to provide critical user interfaces. The Army has long recognized the capability that flat panel displays provide and has developed and adapted this technology to improve mission capability for its Soldiers.

The Army's FDC at ASU is developing flexible display technologies that will significantly improve Soldiers' operational field capabilities by providing them with lightweight, large-format displays that can be folded or rolled up for easy storage and transport. (U.S. Army photo courtesy of FDC ASU.)

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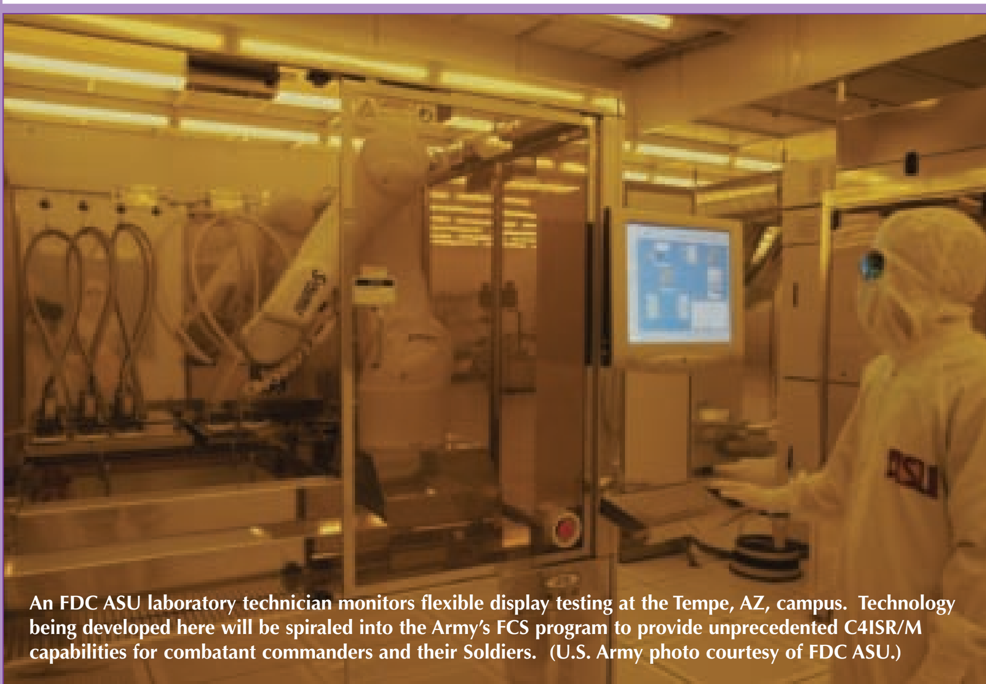

An FDC ASU laboratory technician monitors flexible display testing at the Tempe, AZ, campus. Technology being developed here will be spiraled into the Army's FCS program to provide unprecedented C4ISR/M capabilities for combatant commanders and their Soldiers. (U.S. Army photo courtesy of FDC ASU.)

As Army transformation unfolds through the Future Combat Systems (FCS) program, the ability to perform essential command, control, communications, computers, intelligence, surveillance, reconnaissance/mobility (C4ISR/M) functions for combat vehicles and dismounted warfighters is vital. These applications will require some kind of compact, thin-profile display. Unfortunately, key flat panel display features being produced for today's commercial electronics market make them unsuitable for emerging military applications. Conventional displays tend to consume too much power and are usually made out of glass. This feature means that they require expensive and bulky "ruggedization" before they can be incorporated into military systems, adding significant size and weight to the actual component. For the dismounted Soldier, the high-power requirements of current displays compel the Soldier to bear the additional weight of batteries during operations.

Since the late 1990s, the Defense Advanced Research Projects Agency and the Army have been investigating a number of innovative new flat panel display technologies that can be made on unbreakable substrates such as thin metal foils or even sheets of plastic. These "flexible display" technologies would significantly improve many of the size, weight and power characteristics of today's commercial displays. Looking forward, they also promise lightweight, large-format displays that could be folded or rolled up for storage or transportation.

By the early part of this decade, primitive prototypes of a number of flexible display technologies developed under DOD programs had been demonstrated. However, the efforts to develop these prototypes revealed a number of challenges that must be met in order to perfect the technology to the point that it can be reliably manufactured. The principally offshore flat panel display industry has proven reluctant to make the investments needed to address these challenges, since the breakability and excessive power requirements of existing displays have not limited their widespread adoption in consumer electronics.

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FDC

In 2004, to accelerate the development of commercial flexible displays to meet military needs, the Army established the FDC at ASU in partnership with the state of Arizona. The FDC is the first research and development (R&D) facility in the world to be exclusively dedicated to work on flexible displays. The FDC was formed through a Cooperative Agreement with the Army Research Laboratory (ARL), Sensor and Electron Devices Directorate, managed in conjunction with the Army Natick Soldier Research, Development and Engineering Center (RDEC). The Cooperative Agreement allows ASU, the Army and industrial partners to work together to achieve a common goal. The initial 5-year phase of this 10-year program represents a $44 million investment by the Army and a comparable matching commitment by ASU. It also includes significant participation by a growing list of industrial partners who pay an annual membership fee and make internal investments in support of development projects at the FDC. The industrial participation is governed by a unique Partnership Agreement that spells out the intellectual property rights for participating organizations. The FDC also collaborates with eight universities through a variety of research focus projects.

The FDC's cornerstone is a state-of-the-art pilot manufacturing facility housed in a dedicated building within a university-owned industrial park about

Assistant Secretary of the Army for Acquisition, Logistics and Technology Claude M. Bolton Jr. examines a small flexible display prototype during a visit to the FDC ASU research facility in February 2005. (Photo by Tim Trumble and Jessica Slater, FDC ASU.)

five miles south of the main ASU campus. Operated by a staff of professional engineers and technicians, the facility includes 17,500 square feet of class-10 cleanroom that houses both a development-scale production line and a Generation II pilot display manufacturing line which produces displays on rectangular substrates 370mm by 470mm. The FDC also contains the research laboratories of a number of ASU faculty and their graduate students, who conduct affiliated longer-range research projects supported by a variety of traditional outside research funding sources.

Partnering With Academia and Industry

FDC activities focus on the issues associated with the fabrication of an array of thin-film transistors on flexible substrates, such as thin stainless steel or a transparent specialty polyester. This challenging piece of large-area microelectronics is the critical subsystem that is required to control an array of electro-optical devices to create a digital display. To complete the display, one of three electro-optic technologies being developed by FDC members is integrated with these thin film transistor panels. Ultra-low-power reflective displays can be made using electrophoretic ink from a Massachusetts Institute of Technology spin-out company, E Ink, or cholesteric liquid crystal films provided by a Kent State University spin-out, Kent Displays of Ohio. Alternatively, vibrant full-color and full-motion video organic electroluminescent displays can be built using materials developed by a Princeton University spin-out, Universal Display Corp. These technologies were chosen because of their compatibility with flexible substrates, power advantages and maturity.

> The demonstration of innovative flexible display technology is how the FDC shows that it is achieving its central mission to develop reliable fabrication techniques that are sufficiently mature to stimulate their adoption by the existing display manufacturing infrastructure.

Because the flexible display characteristics being developed are unlike those of any technology currently available to system designers, the FDC works closely with system integrators to develop technology demonstration devices to showcase the new capabilities. Member companies General Dynamics, Honeywell International, L3 Communications and Raytheon have all contributed to the identification of demonstrator projects whose success will help meet the technical requirements of their road maps for future system offerings. The display requirements for these demonstrator projects help define the detailed FDC development program's objectives.

This past summer the FDC successfully demonstrated a fully functional concept device incorporating a flexible display at the Army Future Force Warrior C4ISR On the Move exercise at Fort Dix, NJ. With customer funding and management support coordinated by teams at the Natick Soldier RDEC, a rugged and compact networked PDA was developed for use by individual infantry rifleman squad members.

This Soldier Flex PDA is the first demonstrator candidate for transition to Program Executive Office Soldier from the FDC. It features a rugged low-power reflective display and weighs only 13 ounces. By contrast, ruggedized

Soldiers evaluate Future Force Warrior program equipment during a training exercise. Flexible displays will be another component added to the Soldier's arsenal of lightweight communications and sensory equipment thanks to the world-class research being conducted at FDC ASU. (Photo by Sarah Underhill, Natick Soldier Systems Center.)

The ASU Research Park is home to the first R&D facility in the world exclusively dedicated to flexible display development. The FDC's principal focus is to fabricate an array of thin-film transistors on flexible substrates. FDC's R&D initiatives led to the testing of the Soldier Flex PDA during the Future Force Warrior C4ISR On the Move exercise at Fort Dix this past summer. (Photo courtesy of ASU.)

PDAs featuring conventional glass liquid crystal displays typically weigh as much as 20 pounds. The reflective display technology in the Soldier Flex PDA can be viewed using night vision goggles using only ambient illumination, reducing the Soldier's night vision signature. Programs are underway with the ARL Human Research and Engineering Directorate and Natick human factors engineers to investigate more effective uses of this new capability. The demonstration of technology capabilities to Army users is a key element in the Army's insertion plan.

The demonstration of innovative flexible display technology is how the FDC shows that it is achieving its central mission to develop reliable fabrication techniques that are sufficiently mature to stimulate their adoption by the existing display manufacturing infrastructure. Because this approach necessarily involves the use of new materials and the adoption of unconventional manufacturing processes, it is crucial to engage industrial partners from these parts of the supply chain as early as possible. For such companies, the FDC provides a unique integrated development environment in which they can create and test new products for the emerging field of flexible displays and microelectronics.

FDC member DuPont-Teijin Films is developing a novel high-temperature polyester film that they hope will become the substrate of choice for flexible or printed electronics. Similarly, in the critical area of manufacturing equipment, FDC member EV Group (EVG) has developed a unique tool for the coating of ultra-high uniformity micrometer-thick films of unconventional materials onto large area substrates. The FDC served as the beta-test site for this tool and, as a direct result, EVG recently received an order for a number of these new machines. Finally, a modification to an Azores stepper sponsored by the U.S. Display Consortium (USDC) that enables compensation for the distortion in plastic substrates caused by transistor array fabrication processes has stimulated commercial interest in the modification of tools in existing display fabrication facilities.

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The Army's FDC at ASU represents a pioneering approach to developing technologies to meet warfighter-specific needs in a world in which the American industrial base has become more knowledge-intensive and less manufacturing-intensive. To achieve this objective, a network of world-class partnerships and a dedicated physical infrastructure have been established to create a unique venue for the developing advanced technology and associated manufacturing processes. The FDC has shown worldwide leadership in the development of large-area, low-temperature amorphous silicon microelectronics, and has begun to receive recognition for this at international meetings and in the trade press. After less than 4 years of operation, integrated systems incorporating innovative displays developed by the FDC have already been demonstrated, and the Center is on track to achieve initial technology insertion by decade's end.

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DR. GREGORY B. RAUPP is Professor of Chemical Engineering (Ch.E.) at ASU and FDC Director at ASU. He received his B.S.Ch.E. with Distinction from Purdue University, M.S.Ch.E. from Purdue University and Ph.D. from the University of Wisconsin-Madison. Prior to becoming the FDC Director in 2004, Raupp was ASU's Associate Vice President for Research; and from 1999-2002, he was the Associate Dean for Research in the Fulton School of Engineering. He has published more than 115 technical papers and is the holder of three U.S. patents.